REPORT OF SURVEY CONDUCTED AT

CINCINNATI MILACRON, INC.
CINCINNATI, OH

MAY 1997

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Best Manufacturing Practices

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Foreword

This report was produced by the Best Manufacturing Practices (BMP) program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective toward this goal is simple: to identify best practices, document them, and then encourage industry and government to share information about them.

The BMP program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management – all areas which are highlighted in the Department of Defense's 4245-7.M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource in helping companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to learn from others' attempts and to avoid costly and time-consuming duplication.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at Cincinnati Milacron, Cincinnati, Ohio conducted during the week of May 12, 1997. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from government, industry, and academia throughout the U.S. and Canada – *so the knowledge can be shared.* BMP also distributes this information through several interactive services which include CD-ROMs, BMPnet, and a World Wide Web Home Page located on the Internet at http://www.bmpcoe.org. The actual exchange of detailed data is between companies at their discretion.

Over the years, Cincinnati Milacron has made great strides in its transition to become a better-balanced, more global company with the ideal resource and product mix to grow on a consistent, profitable basis. Despite its global ambitions, the company still maintains its basic core values of customer satisfaction, employee opportunity, and integrity in all that it does. Among the best examples were Cincinnati Milacron's accomplishments in metrology services; building a culture of leaders; machine tool product development process; carburizing process inspection; automatic test system; and spindle carrier runoff.

The Best Manufacturing Practices program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this one on Cincinnati Milacron expand BMP's contribution toward its goal of a stronger, more competitive, globally-minded, and environmentally-conscious American industrial program.

I encourage your participation and use of this unique resource.

Ernie Renner
Director, Best Manufacturing Practices

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Section 1

Report Summary

Background

In 1884, Cincinnati Milacron, Inc. began as a small shop, known as the Cincinnati Screw and Tap Company, which served local industry. Five years later, the company saw the future in milling machines, and changed its name to the Cincinnati Milling Machine Company to reflect its new direction. Over the years, the company grew and expanded its product line (e.g., precision grinding machines, numerical controls, machine tools, plastics injection molding machines) and, in 1970, adopted its present name. Today, Cincinnati Milacron is a global leader in industrial processes, products, and services including plastics processing machinery, moldmaking equipment, composites processing systems, flexible manufacturing cells, metalworking fluids, carbide wear parts, and industrial magnets.

With its corporate headquarters located in Cincinnati, Ohio, Cincinnati Milacron maintains numerous U.S. and international operations, employs 12,500 personnel worldwide, and achieved $1.7 billion in revenues for 1996. The BMP survey focused on the company's Cincinnati-based Machine Tool Group which serves a broad range of markets such as job shops, and the automotive and aerospace industries. Among the best practices documented were Cincinnati Milacron's metrology services; building a culture of leaders; machine tool product development process; carburizing process inspection; automatic test system; and spindle carrier runoff.

The driving force behind Cincinnati Milacron came from its founder, Frederick A. Geier. He championed an uncompromising vision and dedication to the company, its employees, and the surrounding community. This outlook was carried on by his son, Frederick V. Geier, and his grandson, James A. D. Geier. The Geier family legacy guided Cincinnati Milacron to outstanding success and growth; promoted a family atmosphere for its employees; sponsored community projects; and gave selfless contributions to the city of Cincinnati.

Although strong supporters of the community, the Geier family always downplayed their contributions. Upon accepting the Greater Cincinnati Chamber of Commerce's 1996 Great Living Cincinnatian Award, James Geier said of their family, "Our attitude has always been: the community has been good to the Geiers and we have always tried to reciprocate." Three generations of Geiers have dedicated themselves to numerous community projects, including the Community Chest (forerunner of United Way) and United Way campaigns. Most notably is the Geier Family Lodge which was built for Cincinnati Milacron's locally-sponsored boy scout troop, the first industrial-sponsored troop in the United States. The Lodge, built with logs brought down from Canada, was completed in 1957 and features a totem pole that dates to 1932. Today, the Lodge still sits adjacent to the corporate headquarters, and is available to anyone for scouting functions.

The Geier family also emphasized a strong family atmosphere at Cincinnati Milacron. The company traditionally sponsors holiday parties and open houses; maintains on-site recreation facilities; and promotes employee activities. Every few years, Cincinnati Milacron hosts a Family Day for its employees and their families. A special attraction is the 1884 Room, located on the top floor of the corporate headquarters. Remembering the past is a strong tradition at Cincinnati Milacron. Upon stepping off the elevator, visitors are transported back to 1884, the year the company was incorporated. The entryway recreates, in three-quarter scale, the corner of Pearl and Plum Streets in downtown Cincinnati, complete with cobblestones, gaslights, and the train station of the old Cincinnati, Indianapolis, St. Louis & Chicago Railroad. Across the street is a replica of the original shop, the Cincinnati Screw and Tap Company. Upon entering the shop, visitors can view the tall, stand-up desk to the left where business transactions took place. All the machines within the shop are authentic and appear much as they did over a century ago. Two small executive dining rooms are also located on this floor, and feature murals with scenes from the 1880s.

Over the years, Cincinnati Milacron has made great strides in its transition to become a better-balanced, more global company with the ideal resource and product mix to grow on a consistent, profitable basis. In the early 1990s, Cincinnati Milacron began implementing a corporate-endorsed

leadership philosophy based on principles developed by Stephen Covey. This philosophy has played a role in enabling the company to regain its competitive position and set about building a new culture of leadership at all levels. The result was the evolution of a proactive empowered culture characterized by customer focus; active involvement by all employees; attention to detail; and balance between production and production capability. Despite its global ambitions, Cincinnati Milacron still maintains basic core values of customer satisfaction; employee opportunity; company growth and profitability; and integrity in all that it does. The BMP survey team considers the following practices to be among the best in industry and government.

Best Practices

The following best practices were documented at Cincinnati Milacron:

Item	Page
Machine Tool Product Development Process	5

Cincinnati Milacron has significantly integrated the critical steps of its machine tool product development process by using finite element analysis software tools. Improvements in these software tools now allow for static and dynamic-concept design modal analyses. In turn, new testing tools, based on continuously-improving computer techniques, have improved the models by shortening the design process and reducing material requirements. Tuned damped absorber capabilities have also significantly enhanced the performance of machine tool products.

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Product Development: Wolfpack Process	5

In 1985, Cincinnati Milacron started its Wolfpack Process within the Plastics Machinery Group. The immediate challenge was to establish low cost, high quality products with a short lead time, while the immediate goals were to use significantly fewer parts and lower the product cost. After subsequent revisions of the process, Cincinnati Milacron met its immediate goals and global challenge. The Wolfpack Process is now implemented company-wide.

Item	Page
Carburizing Process Inspection	6

Carburization, a primary heat treatment process, produces case-hardened surfaces with specific case depths and effective hardness values. To obtain reliability measurements, a sample coupon is processed with the test load and analyzed. Over the years, Cincinnati Milacron has transitioned through several coupon types including shim stock, test pins, fracture pins, and bored round stock. Cincinnati Milacron has now developed a unique coupon for in-process inspection which accurately measures effective case depth in the test load after carburizing.

Item	Page
Automatic Test System™	7

In the early 1970s, most machine alignments were performed manually by using mechanical instruments. Computerized data acquisition had limited applications, and alignment quality depended on the skill of the operator. To resolve this situation, Cincinnati Milacron developed the Automatic Test System™, a computerized measurement system, which can perform quick, accurate alignments of machining centers and enforce consistent runoff procedures.

Item	Page
Cellular Manufacturing System	7

In the early 1990s, Cincinnati Milacron was faced with the challenge of reconfiguring its prismatic parts manufacturing system to accommodate 500 new part numbers. Redesigned as subsystems, the Cellular Manufacturing System features upgraded equipment, a new manufacturing philosophy, and a team membership approach.

Item	Page
Quality Assurance via an Artifact	8

Cincinnati Milacron developed a highly-efficient Quality Assurance system for eliminating defective parts being shipped to assembly and reducing the dependency on final inspections. Although various quality assurance procedures were implemented into the system, axis alignment, reliability, and verification presented difficult challenges. In response, Cincinnati Milacron developed an artifact suitable for a high production process.

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Spindle Carrier Runoff	8

Previously, Cincinnati Milacron used a single test stand for its spindle carrier runoff operations. This manually-controlled operation was time consuming, relied on the technician's skill, and provided limited data in a tabular format.

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To improve its operations, Cincinnati Milacron installed new stands which test two spindle carriers simultaneously during the runoff operations. An automatic runoff cycle allows operators to perform various tests within the same timeframe and capture data in a graphical format.

Temperature Control with Environmental Responsibility — 9

In the late 1980s, Cincinnati Milacron was faced with the challenge of producing more accurate, higher tolerance machine tools at a lower market price. Statistically, machine tolerance requirements increase 30% every six years. Recognizing that temperature control was a necessity for meeting this challenge, Cincinnati Milacron established a system which met production requirements and allowed the company to work with the local manufacturing community in an environmentally-conscious, manufacturing initiative.

Building a Culture of Leaders — 9

Cincinnati Milacron has implemented a corporate-endorsed leadership philosophy based on principles developed by Stephen Covey. The initiative began in the early 1990s as a way to revitalize the company in response to its declining market share and outmoded corporate culture. During its first hundred years, Cincinnati Milacron became an industrial giant, but in the process developed a stifling, paternalistic culture that limited its ability to compete in a rapidly changing global marketplace. The company recognized that major changes would be required to regain its competitive position and set about building a new culture based on leadership at all levels.

Customer Satisfaction Interview Process — 10

Cincinnati Milacron's customer satisfaction telephone interviews have provided excellent feedback and very useful information. Customers that indicate strong disapproval receive prompt attention which can prevent the loss of a customer. Distributor problems and weaknesses in sales coverage can be identified by the surveys and corrected. The survey is proving to be an excellent tool for continuous improvement and measuring customer satisfaction.

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Dynamic Quality System — 11

Cincinnati Milacron has developed and implemented a Dynamic Quality System based on the documentation of all processes, conformance measurements, and continuous improvements. The Dynamic Quality System was designed to be a fully-documented system with processes for internal auditing, corrective action, nonconforming material, and machine audits.

Metrology Services — 12

Cincinnati Milacron has an extensive and sophisticated Metrology Services Department that provides calibration services for more than 30,000 different pieces of measuring and test equipment. The department maintains a stable, environmentally-controlled laboratory with traceability to the National Institute of Standards and Technology.

Technical Training — 12

Cincinnati Milacron believes that selling a customer a product is only the first step in a long-term partnership. Training, as a key element, helps ensure that Cincinnati Milacron's customers will receive the best performance from the equipment they purchase. The Technical Training Department supports customer training programs and provides training for Cincinnati Milacron's personnel and distributors.

Information

The following information items were documented at Cincinnati Milacron:

Item	Page

Advanced Composites Technology Business Unit — 15

To handle composite technology products, Cincinnati Milacron developed the Advanced Composites Technology Business Unit. The unit provides Cincinnati Milacron's aerospace customer base with a singular point of responsibility for high technology content composite materials manufacturing systems, and is responsible for complete specification, design, installation, and support of research and development.

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Reliability and Maintainability Guidelines — 15

In 1994, Cincinnati Milacron set up a team to ensure that the company was complying with the 1993 reliability guidelines, published jointly by the Society of Automotive Engineers and the National Center for Manufacturing Sciences, Inc., for manufacturing machinery and equipment. The team developed specific checklists to ensure comprehensive consideration of reliability and maintainability. The resulting guidelines support Cincinnati Milacron's internal development and support processes, and comply with the 1993 reliability guidelines.

Precision Engineering — 16

Cincinnati Milacron produces precision metalworking machines and products. The company recognizes that customers want to purchase accurately-constructed machines and products as well as equipment that produces accurate products. Consequently, Cincinnati Milacron identified and measured the elements that contribute to inaccuracies in workpieces produced on machining centers, and incorporated the findings back into the product design and development processes to improve resultant accuracies.

Continuous Improvement: Machete Program — 16

Known for its quality products, Cincinnati Milacron is committed to continuous improvement through its Total Quality Leadership approach. A key element of this approach is the Machete program which encourages total employee involvement in Cincinnati Milacron's continuous improvement efforts, and uses a disciplined process to address employee improvement suggestions.

Sheet Metal Art to Part — 17

Cincinnati Milacron is in the process of implementing a concurrent systems strategy. Part of that strategy will be the capability to design and produce a sheet metal part without paper and with minimal human analysis. Major manufacturing objectives include 100% conformance to specifications; improved facility and equipment usage; reduced manufacturing costs; and on-time delivery.

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Unit Assembly Test Stands — 17

Cincinnati Milacron has developed and implemented four subassembly test units for its assembly process. Developed as low cost and low technology ideas, these units reduce costs and runoff time of the machining centers; improve the quality and reliability of products; ensure consistent test procedures are followed; and reduce runoff times for acceptance testing of finished products.

Safety and Wellness for Employees Program — 18

The Safety and Wellness for Employees program represents an important aspect of Cincinnati Milacron's commitment to its employees. Through this program, Cincinnati Milacron provides and maintains safe, healthy work environments; promotes safety and wellness training; and complies with safety requirements and regulations.

Service Parts Division — 18

Cincinnati Milacron's Service Parts Division provides post sales service and supplies all repair parts for milling, grinding, and turning machines built since 1884. The division consists of customer communications, technical services, inventory control, expediting, purchasing, pricing, microfilming, programming, assembly, shipping, and warehousing. Essential to the Service Parts Division's operation are accessibility and part availability.

Point of Contact

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Section 2

Best Practices

Design

Machine Tool Product Development Process

Machine tool designing involves numerous critical steps including comprehending and controlling various design variables, such as cutting forces, structural stiffness, motion, vibration, noise, dynamic stiffness, natural frequencies, and damping. Previously, Cincinnati Milacron verified dynamic characteristics of machine tool designs through strain gauge measurements and hand calculations. The process required several concept and design cycles to produce multiple prototypes that were then subjected to testing and redesigning until the goals were met. Results, verified with experimental versus analytical techniques, typically needed additional redesigning and further prototypes which increased the cost and product development cycles. In response, Cincinnati Milacron significantly integrated the critical steps of its machine tool product development process by using finite element analysis (FEA) software tools.

Improvements in FEA software tools now allow for static and dynamic-concept design modal analyses. In turn, new testing tools, based on continuously-improving computer techniques, have improved the confirmation of the models, thereby shortening the design process and reducing material requirements. This is achieved by using sequential static and dynamic FEA modeling and simulation with the applicable loads, material specifications, and restraints applied. If the results are unsatisfactory, the design is iterated and the simulation repeated until a viable solution is achieved, prior to physical prototyping.

Cincinnati Milacron coordinates solid models by using translation software to move concept-design data electronically from the design station into the analysis model. The static analysis ensures that key stiffness stress and deflection criteria are satisfied before the more extensive dynamic analysis is conducted. This process, along with strong troubleshooting and test expertise, has enabled Cincinnati Milacron to develop numerous, patented methods for overcoming vibration and related dynamic structural problems. Tuned damped absorber capabilities have significantly enhanced the performance of machine tool products. Other engineered damping solutions are available through Cincinnati Milacron's dynamic analysis based capabilities. The unique damping devices are used to satisfy the required machine performance.

Not only does Cincinnati Milacron's machine tool product development process provide better structural integrity predictions, but it greatly reduces the number of iterations needed for an effective design. In addition, the process has successfully reduced the number of prototypes to one, required fewer tests, and decreased the design-to-market time for new products. Structural integrity can be displayed during the machine-concept phase which increases and expedites the human perception of critical performance. Resource costs to complete development are also reduced along with a lowered risk of non-performance.

Product Development: Wolfpack Process

Cincinnati Milacron competes in the plastics processing and metalworking markets. In 1985, the company started its Wolfpack Process within the Plastics Machinery Group which faced serious foreign competition. The immediate challenge was to establish low cost, high quality products with a short lead time, while the immediate goals were to use significantly fewer parts and lower the product cost. After subsequent revisions of the process, Cincinnati Milacron met its immediate goals and global challenge. The Wolfpack Process is now implemented company-wide.

The evolution to rapid product development was based on the teamwork and competitiveness typified by a wolf pack, hence the name. By recognizing the costs associated with delayed products, Cincinnati Milacron hastened the development of teams by replacing its earlier, sequential product design and development with concurrent engineering. Cross-functional teams were challenged and empowered to deal with the full scope of product development issues including the active integration of customers and suppliers into the process. As

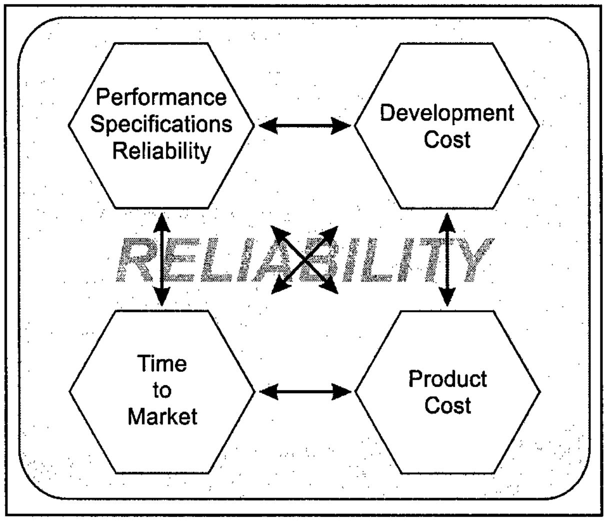

Figure 2-1. Product Development Trade-Offs

indicated in Figure 2-1, the team conducted trade-offs and prioritized recommendations based on the expected product life cycle.

The process uses defined project phases (feasibility; definition; concept; design and build; runoff and test; and production), each with established objectives and formal approvals to proceed. Incorporated within the Wolfpack Process are numerous procedural benefits such as requirements definition, top level support, team colocation, and risk analysis. While each benefit provides some intrinsic gain, the principal contribution is to enhance the strong sense of team within the participants.

By substantially integrating customers and suppliers into the Wolfpack Process, Cincinnati Milacron has directly improved its vendor quality while providing significant performance enhancements for its customers within cost targets. Figure 2-2 shows the significant parts reduction achieved for one of the company's recent machine tool product designs.

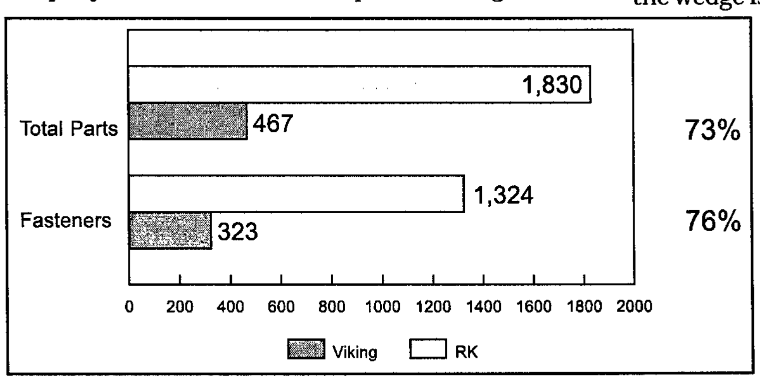

Figure 2-2. Part Content Comparison

Test

Carburizing Process Inspection

Cincinnati Milacron performs various in-house heat treatment processes for specified surface hardness requirements. Carburization, a primary heat treatment process, produces case-hardened surfaces with specific case depths and effective hardness values. Reliability measurements are obtained from a sample coupon (processed with the test load) and analyzed to verify the case depth and hardness value. Over the years, Cincinnati Milacron has transitioned through several coupon types including shim stock, test pins, fracture pins, and bored round stock. Although data obtained from these types focus on carbon profile and surface hardness, they do not accurately or efficiently measure effective case depth. Cincinnati Milacron has developed a unique coupon for in-process inspection which accurately measures effective case depth in the test load after carburizing.

Cincinnati Milacron uses continuous oxygen monitoring (rather than intermittent sampling) to achieve a more efficient and effective process. Continuous monitoring of the carburizing chamber atmosphere shortens the overall carburizing process and provides better control by boosting or employing an elevated carbon-rich atmosphere during the initial heating. Since 1993, Cincinnati Milacron has tailored its carburizing process with a standardized wedge-shaped coupon. The initial coupon (1" x 3/8" x 6" flat bar stock) has the same relative carbon content as the test load. After carburizing with the test load, the coupon is ground to a standard wedge profile. Depth measurements along the slope are marked, and hardness values are recorded at the specified effective case depth. If the wedge is beyond specification limits, the carbon profile is determined with a spectrometer. Then, the operator calculates the corrective heat treat cycle (e.g., rerun time, temperature, carburizing level) by entering the carbon profile information into a computer program.

By using ground wedge profiles for its in-process inspection, Cincinnati Milacron gains several improvements in accuracy and efficiency. The carburizing process checks and releases the test load in 2.5 hours, while prior meth-

ods required inspection times of 4 to 24 hours. Effective case depth is now measured directly, and only one coupon is required to obtain data for the effective case depth and the carburized case depth. All operations can be performed by the operator with a 98% initial success rate. With these improvements, Cincinnati Milacron has decreased cost during production and increased product reliability.

Production

Automatic Test System™

In the early 1970s, most machine alignments were performed manually by using mechanical instruments. Computerized data acquisition had limited applications, and alignment quality depended on the skill of the operator. To improve alignment quality and eliminate inconsistent practices during machine runoff testing, Cincinnati Milacron's Machine Tool Group developed the Automatic Test System™ (ATS) primarily for its Maxim machine runoff.

As a computerized measurement system, ATS performs quick, accurate alignments of machining centers and enforces consistent runoff procedures. The system can detect geometric errors in the roll, pitch, and yaw of axes as well as straightness, squareness and positioning errors. ATS uses a Pentium Processor and Precision Engineering Measurement System (PEMS) software. This Windows-based software was developed in-house using Visual Basic. The on-line help feature gives precise steps for checking and correcting machine alignments, and the PEMS software provides visual changes in geometric errors.

ATS maximizes the accuracy of the alignment and improves the overall quality of the process. The PEMS software can adapt to new machine types and provide detailed information on each test performed through easy bookkeeping capabilities. By using ATS and the PEMS software, Cincinnati Milacron has reduced alignment time from 30 to 8 hours per machine.

Cellular Manufacturing System

In the early 1990s, Cincinnati Milacron was faced with the challenge of reconfiguring its prismatic parts manufacturing system (a projected 40,000-hour workload increase) to accommodate 500 new part numbers. Redesigned as subsystems, the Cellular Manufacturing System features upgraded equipment, a new manufacturing philosophy, and a team membership approach.

Cincinnati Milacron replaced the original 12 stand-alone T-Line machines with a four-machine T-30 Flexible Machining Cell (FMC) and a four-machine Maxim 630 FMC. To provide additional flexibility to the FMCs, a Cincinnati Milacron Cincron cell controller was installed in each cell. As a high-capability computer program, Cincron manages the material handling and machining of parts by interfacing with a Programmable Logic Controller and a Direct Numerical Control system, and performs production planning functions (e.g., load scheduling, tool and fixture identification, production tracking) off-line which minimizes spindle downtime. Cincron's most notable feature is its tool inventory capability which eliminates redundancy and reduces tooling requirements by 40%. By coupling embedded chips in the tool holders with Cincron's capabilities, Cincinnati Milacron eliminated erroneous tool selection by operators. Other upgrades included an air conditioning system to maintain room environments since the equipment operates in tolerance ranges of ten thousandths of an inch, and a coolant filtration and temperature stabilization system to further assure accuracy and consistency.

Besides equipment upgrades, Cincinnati Milacron initiated a new manufacturing philosophy consisting of four basic elements: efficient capacity use to meet low and high volume demands; increased agility and flexibility; increased product velocity throughout the system; and a focus on quality, delivery, and value. A voluntary team has also been started. In addition to being trained for their own tasks, members can receive cross-training, allowing them to gain ownership of the entire process. Factory floor, maintenance, programming, and systems members are represented on the voluntary teams.

By the successful integration of its subsystems, the Cellular Manufacturing System demonstrates Cincinnati Milacron's innovative manufacturing approach. Benefits from this system include reducing lead time by 25%, decreasing floor space by 50%, increasing production by 20%, and raising efficiency by 10%. Improvements in efficiency resulted in eliminating outsourcing and reducing scrap and rework by 25%.

Quality Assurance via an Artifact

By combining teamwork, state-of-the-art equipment, and the Cincron computer program, Cincinnati Milacron developed a highly-efficient Quality Assurance system. The system's goal is to eliminate defective parts being shipped to assembly and reduce the dependency on final inspections. Various quality assurance procedures (e.g., temperature control, hydraulic fluid temperature control, fixturing) were implemented into the system. Cincinnati Milacron determined that in-process control and final inspection procedures could be performed by a factory floor team. However, axis alignment was a complicated process which required a machine to be taken out of service for an extended period of time. Further complicating this process was the difficultly in reliably predicting when axes needed alignment and verifying correct alignments afterwards. To resolve this situation, FMC teams and the Research and Development Department developed an artifact suitable for a high production process.

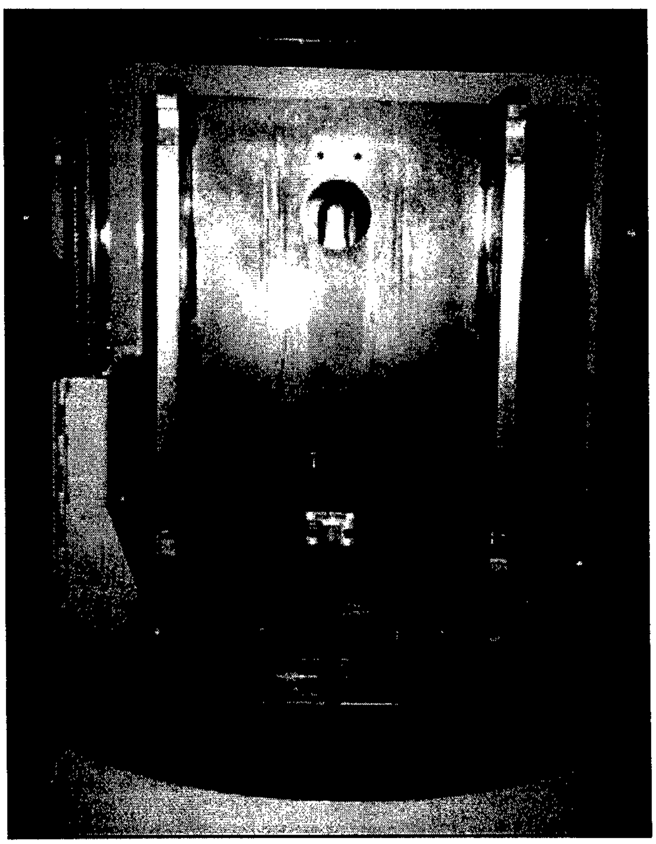

Figure 2-3. Artifact

Permanently mounted on a pallet, the artifact (Figure 2-3) has six locating pads and two strategically-located bored holes which provide data in three planes. Cincinnati Milacron also developed a procedure to ensure that data entered into the Cincron control system was accurately collected from the artifact. A baseline is established through laser alignment and a probe of the artifact. The artifact is then probed daily and its data is compared to the baseline. If the machine exceeds the established tolerance limits, then it is realigned.

The artifact has improved the quality and accuracy of the Quality Assurance system. As a result, Cincinnati Milacron decreased defective parts being shipped to assembly by 9% during a one-year period, and greatly reduced the dependency on final inspections.

Spindle Carrier Runoff

Previously, Cincinnati Milacron used a single test stand for its spindle carrier runoff operations. This manually-controlled operation required three hours to adjust speeds and verify temperatures for each spindle carrier tested, and eight hours for the test runoff including cool down cycles. Additionally, the operation relied on the technician's skill and provided limited, difficult-to-read data in a tabular format. To improve its spindle carrier runoff operations, Cincinnati Milacron's Machine Tool Group changed the test stands (Figure 2-4).

The new stands can test two spindle carriers simultaneously during the runoff operations. Cincinnati Milacron also installed an automatic runoff cycle so operators can perform a wider variety of tests within the same timeframe and capture more data in a graphical format. The additional data is also being used for future design and technology development.

The new test stands have increased the efficiency of Cincinnati Milacron's spindle carrier runoff operations, doubled the number of spindle carriers tested within a timeframe, and reduced manual input requirements for each test. Other benefits include consistent product quality with lower warranty returns from the customer, and problem-solving capabilities prior to releasing the carrier for final assembly.

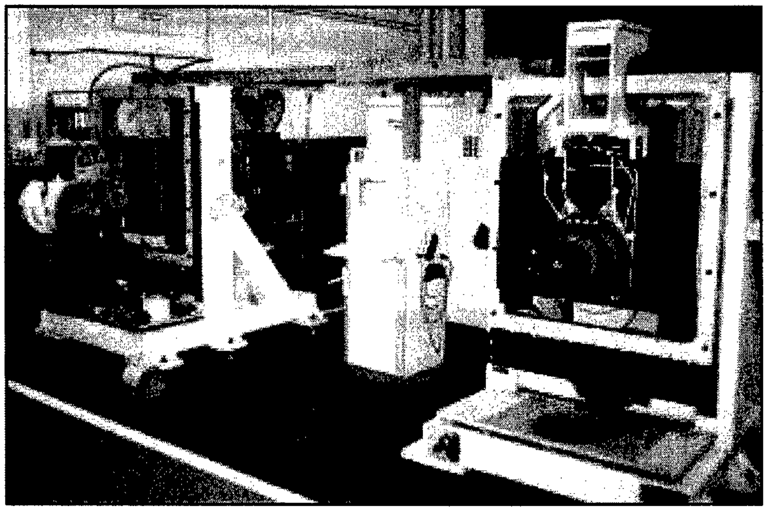

Figure 2-4. Spindle Carrier

Facilities

Temperature Control with Environmental Responsibility

In the late 1980s, Cincinnati Milacron was faced with the challenge of producing more accurate, higher tolerance machine tools at a lower market price. Statistically, machine tolerance requirements increase 30% every six years. Typical machining center tolerances have increased from the one thousandth of an inch range of the 1970s to less than 20% of that in the 1990s. During the same timeframe, rapid traverse rates and spindle speeds have increased by 400% and 300%, respectively, while market prices have decreased by 30%. Cincinnati Milacron recognized that temperature control was a necessity for meeting this challenge.

Existing resources were available to Cincinnati Milacron. A coal-fired steam plant was located on-site and a portion of the production complex already had air handling ducts in place. The existence of the steam plant dictated the use of absorption chillers in lieu of chlorofluorocarbons. By working with a company that dealt in secondhand equipment, Cincinnati Milacron only needed to purchase two new chillers. The rest of the equipment was secured in used, but excellent condition at a greatly reduced price, including cooling towers and pumps.

Cincinnati Milacron's temperature control system has proven successful. Not only does the system meet production requirements, but it allows the company to work with the local manufacturing community in an environmentally-conscious, manufacturing initiative. Cincinnati Milacron also reconfigured its coal-fired steam plant to burn supplemental fuels. This action eliminated the high costs previously endured by the company when it sent a substantial amount of by-products (produced as oils) to disposal facilities. The expected closure of landfills to wood products presented another challenge. Cincinnati Milacron purchased a wood chipper to dispose of its wooden pallets, and installed an automated system which incorporates the chips into the coal-burning process.

In addition to its own, Cincinnati Milacron has set up contracts with several local companies to beneficially use their by-products, including wood and oil filter media. By charging a fee for this service, Cincinnati Milacron can partially offset its expenses and more fully utilize natural resources. This initiative has enabled the company to generate up to 10% of its steam requirements, while partially eliminating a disposal situation for itself and the local community.

Management

Building a Culture of Leaders

Cincinnati Milacron's Machine Tool Group has implemented a corporate-endorsed leadership philosophy based on principles developed by Stephen Covey. The initiative began in the early 1990s as a way to revitalize the company in response to its declining market share and outmoded corporate culture. During its first hundred years, Cincinnati Milacron became an industrial giant, but in the process developed a stifling, paternalistic culture that limited its ability to compete in a rapidly changing global marketplace. The company recognized that major changes would be required to regain its competitive position and set about building a new culture based on leadership at all levels.

The first step was to understand and assess the current state of the company. Cincinnati Milacron took the time and effort to analyze its beginning and characterize the state of the company. An employee opinion survey revealed that Cincinnati Milacron was a company without a clear sense of direction and purpose. It was a reactive company,

run by top-down directives, and driven by efficiency rather than effectiveness. Employees did what they were told but did not participate in improving performance or decision making. There was little employee involvement with customers. Employees avoided risk taking and feared failure.

With a clear understanding of the state of the company, senior management defined and implemented a new direction to develop a culture of leadership at all levels. The new culture of effectiveness would be proactive and based on personal responsibility with ownership defined by a vision of the future and guided by a set of core values. In 1989, the new corporate vision and core values were defined by the senior management team. They realized that changing behavior and culture does not happen overnight. It requires long-term education, leadership, and reinforcement. Management set up an environment that provides the necessary knowledge and opportunities to experience leadership, and encourages a desire to change.

The cornerstone of the culture of leadership is the Covey "Seven Habits of Highly Effective People" philosophy. Senior management attended training at the Covey Institute in Utah. A Covey facilitator was brought to Cincinnati, Ohio to train a core group of management personnel. A three-day Leadership Workshop was also developed for presentation to all employees. The Leadership Workshop is presented away from the work environment and provides the foundation in the Seven Habits concepts. The three-day course provides the basic knowledge needed for change, but is not sufficient to change behavior over time. A Leadership Renewal program was established which provides a structure for continuous integration of effective leadership principles into the every day personal lives of employees and the culture of the company. The renewal program provides a series of five modules offered to employees on a periodic basis. These are company-directed modules which provide programs and activities to help all employees develop positive habits of behavior and greater levels of personal and professional effectiveness.

The program has been implemented throughout the ranks of the company's supervisory and professional level employees. Of the salaried employees, 90% have completed the three-day Leadership Training program, and a high percentage have completed one or more renewal modules. In the past two years, the company has devoted nearly 20,000 hours of training to leadership.

The result has been the evolution of a proactive empowered culture characterized by customer focus; active involvement by all employees; attention to detail; and balance between production and production capability. These practices and habits are being integrated to help employees deal with the constantly changing world around them. The initiative has and will continue to have long-term, profound impact by improving individual and organizational effectiveness and helping employees balance day-to-day relationships both at work and away from work.

Customer Satisfaction Interview Process

In 1994, Cincinnati Milacron began a customer satisfaction survey. The survey, developed and performed by an outside consultant, was conducted by telephone and focused on products which the customer had in service for six months to one year. Questions dealt with Cincinnati Milacron's products as well as its competitors.

In 1996, Cincinnati Milacron initiated monthly surveys, conducted by employees who are members of the Customer Satisfaction Team. This is a special group that has been established to obtain feedback from customers about their satisfaction with Cincinnati Milacron's products and services, as well as their perceptions about the company and its distributors in general. About 40 customers are surveyed each month in reference to specific machine tools that were installed in their plant. The interviewer asks about 40 questions on satisfaction and perceptions using a ten-point scale, ranging from "extremely satisfied" to "not satisfied at all" for each answer. Results are carefully reviewed by Customer Service personnel, engineering staff, and management. The responses, to date, have been extremely frank. Information from the survey is used as an input to measure the effectiveness of the managers of each business unit.

Cincinnati Milacron's customer satisfaction telephone interviews have provided excellent feedback and very useful information. Customers that indicate strong disapproval receive prompt attention which can prevent the loss of a customer. Distributor problems and weaknesses in sales coverage can be identified by the surveys and corrected. The survey is proving to be an excellent tool for continuous improvement and measuring customer satisfaction.

Dynamic Quality System

Cincinnati Milacron's Machine Tool Group (MTG) has developed and implemented a Dynamic Quality System based on the documentation of all processes, conformance measurements, and continuous improvements. Until about three years ago, MTG's quality system was poorly documented, poorly controlled, and haphazard. Besides lacking trained auditors, the system had no formal method for handling non-conforming material; corrective and preventive action; or internal control.

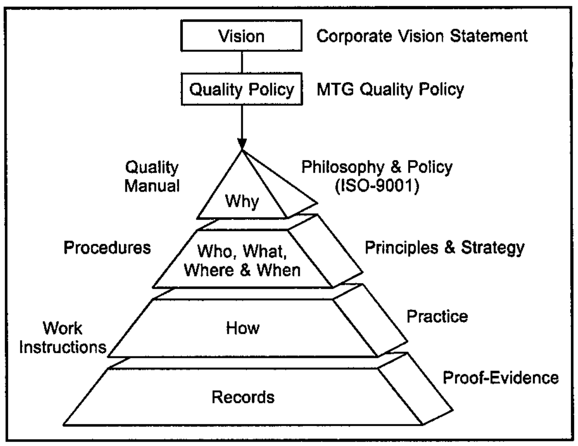

Figure 2-5. Machine Tool Group's Dynamic Quality System

Cincinnati Milacron's new approach to quality began in 1994 with the objective of becoming ISO-9001 certified. The Dynamic Quality System was designed to be a fully-documented system with processes for internal auditing, corrective action, non-conforming material, and machine audits. The system is based on the corporate vision and supports the MTG Quality Policy, which focuses on customer satisfaction, conformance to requirements, and continuous improvement. Figure 2-5 shows the structure of the Dynamic Quality System.

The focal point of the system is the quality documentation system. Over 300 documents containing policies, manuals, operating procedures, and work instructions are available on-line and in hardcopy at 30 quality documentation centers located throughout the facility. The on-line system uses a commercially-available documentation software program. The combination of the on-line and hardcopy documents ensures that essential information is accessible to everyone who needs it and can be easily updated. Operating procedures and work instructions are available for all equipment and processes in the plant. All work is considered a process and must be documented.

The quality documentation system is reinforced by an effective, internal quality audit process. Nearly 50 internal auditors have been trained. They operate in teams of two, and conduct internal quality audits of key functional areas and processes. Cincinnati Milacron is planning 70 quality audits for 1997. The audits cover all ISO-required elements and help ensure that the company's ISO certification status is maintained. All audit nonconformances are analyzed to determine root causes, and appropriate corrective action is initiated.

MTG has closed-loop processes for corrective action requests, non-conforming material, machine audits, and customer satisfaction. Corrective action requests and non-conforming material reports must be closed out within 30 days. Machine audits and 24 to 40 hours of reliability and verification testing are done on each machine before it is shipped. These processes form feedback loops (Figure 2-6) to all levels of the company from the supplier chain to equipment in the field.

Cincinnati Milacron's Dynamic Quality System provides clearly-defined documented policies and

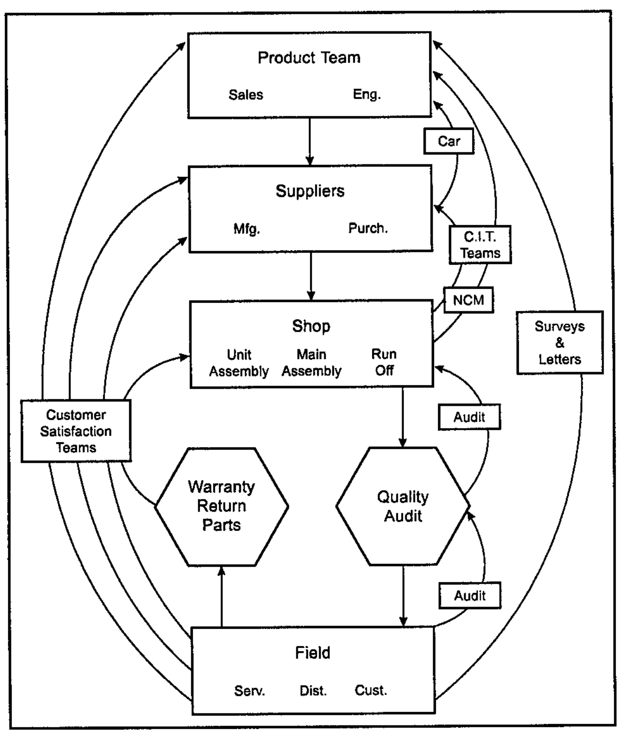

Figure 2-6. Quality System Feedback Loops

procedures, and a baseline for continuous improvement. Well-defined methods for handling corrective action, non-conforming material, and performing audits are clearly specified. The system provides internal control of conformance to requirements; allows for flexibility and variation; and provided the basis for successful achievement of ISO-9001 certification in April 1996.

Metrology Services

Cincinnati Milacron's Metrology Services began as the Electrical Research and Development Group around 1960. Work done on electronic measuring equipment focused mainly on maintenance rather than calibration. In 1970, the Dimensional Group and the Electrical Research and Development Group merged together as the Metrology Services Department, which repaired and calibrated all measurement and test equipment.

Cincinnati Milacron's Machine Tool Group (MTG) has an extensive and sophisticated Metrology Services Department that provides calibration services for more than 30,000 different pieces of measuring and test equipment. The department maintains a stable, environmentally-controlled laboratory with traceability to the National Institute of Standards and Technology. In 1993, Metrology Services installed MET/TRACK®, a new software program produced by the Fluke Corporation, to replace its dBASE III program. MET/TRACK® offers more opportunities for updating the database, maintains historical files on each gauge, customizes reports, performs networking, and provides a more user-friendly operation. Throughout 1994 and 1995, Cincinnati Milacron continued to improve and customize MET/TRACK®. During the same timeframe, MTG switched to a Pratt & Whitney Laser Measurement System for calibrating gauge blocks and achieved as much as 50% time savings in gauge block certification.

In less than one year, MTG's total gauge delinquency decreased from 12% to less than 1% (Figure 2-7). This accomplishment represented the closest that Metrology Services had ever been to meeting its goal of 100% of gauges in the gauge recall system and 0% delinquency. As a world-class facility, Metrology Services uses state-of-the-art equipment; conforms to ISO-9000 requirements and other standards; and strives for customer satisfaction by providing high quality, prompt gauge service at the lowest possible cost.

Technical Training

Cincinnati Milacron believes that selling a customer a product is only the first step in a long-term partnership. Training, as a key element, helps ensure that Cincinnati Milacron's customers will receive the best performance from the equipment they purchase. The Technical Training Department supports customer training programs and provides training for Cincinnati Milacron's personnel and distributors.

The Technical Training Department has a full-time staff of ten professional instructors, each averaging more than 20 years of experience. Instructors are selected from among Cincinnati Milacron's employees who have a broad background of experience, good communication skills, and the ability to develop technical curricula. Each training

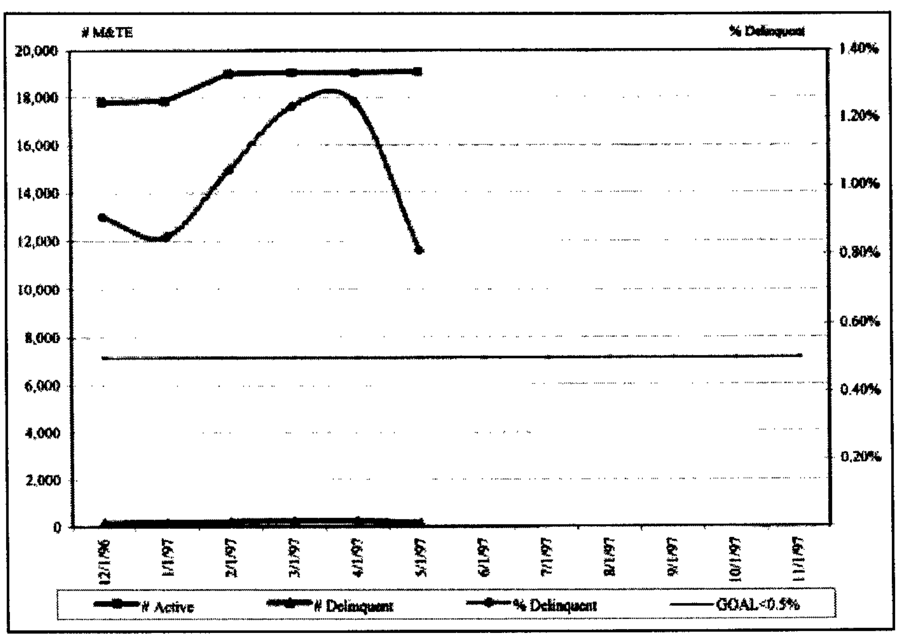

Figure 2-7. Measuring & Test Equipment Calibration Analysis

facility has complete machines, controllers, subunits, and simulators in its laboratory for hands-on training. Regularly scheduled classes are conducted using audio and visual training aids. Hands-on training comprises 50% to 70% of each course. A formal evaluation system provides feedback to students and their companies on the effectiveness of the training. Course evaluations by trainees and their companies support the continuous improvement of the training courses.

The Technical Training Department also offers machine-specific courses which cover operational, programming, and maintenance functions. These courses are designed for owners of Cincinnati Milacron's turning, machining, and grinding equipment. Programmed materials, available in various mediums, allow students to teach themselves. Courses are presented either at the corporate training facility in Cincinnati or at the customer's facility using their equipment. Also available to customers are training specialists who can evaluate customer requirements and recommend existing courses, or create a course of study which meets specific customer requirements. This approach provides great flexibility for meeting customer needs, and represents an integral part of the continuing business relationship that Cincinnati Milacron has developed with its customers.

Training is available on all types of machine tools, and is included in the sale price of most machines delivered to a customer. Additional or special training may also be purchased. Training programs are provided internally to Cincinnati Milacron's employees and distributors at no cost. These programs target assembly and test personnel; field and sales representatives; and maintenance personnel. Revenue generated from the customer training subsidizes the cost of Cincinnati Milacron's internal training program, and supports the advanced facilities and equipment used by the Technical Training Department.

The Technical Training Department plays a key role in other aspects of Cincinnati Milacron besides direct customer support and employee training. Training and training support are important capabilities in generating and maintaining sales. Having well-trained customers significantly reduces warranty expenses for Cincinnati Milacron. The Technical Training Department helps develop new products by proving out documentation, processes, and procedures which ensure that machine specifications and manuals will be accurate and correct. By encountering various customer problems and concerns, the instructors gain experience that aid in product improvement efforts.

Overall, the Technical Training Department represents an important element of customer satisfaction, product development, and marketing. The Department helps Cincinnati Milacron develop a partnership and an enduring relationship with its customers and distributors; assists in developing new products and improving existing ones; and ensures that Cincinnati Milacron's employees are among the best trained in industry.

Section 3

Information

Design

Advanced Composites Technology Business Unit

Composite-related products include tape laying systems, fiber placement systems, development parts, production parts, and manufacturing process consulting. Cincinnati Milacron's initial composite product efforts produced satisfactory performance levels for cost and scheduling problems. Product responsibility was performed through four independent groups: Research and Development; Aerospace; Controls; and Software Products.

To handle composite technology products, Cincinnati Milacron developed the Advanced Composites Technology Business Unit by reorganizing the four groups and incorporating related marketing and customer support. The Advanced Composites Technology Business Unit provided Cincinnati Milacron's aerospace customer base with a singular point of responsibility for high technology content composite materials manufacturing systems. The unit is also responsible for complete specification, design, installation, and support of research and development.

Improvements in Cincinnati Milacron's composite product performance have been particularly optimized by its unique fiber placement design system and programming software. The fiber placement system uses solid model surface designs imported directly from the product's electronic design files using Cincinnati Milacron's translator. The system then generates a fiber placement path, and the simulated animation checks for fiber path and collision warnings. Further processing steps include post processor, ply bundler, and a communications module. The fiber placement programming software analyzes inherent gaps due to the part's geometry. Finite element analysis can also be performed on the processed model by collecting data from the true fiber placement. The analysis reveals stresses which represent the part's structural integrity based on the true fiber placement versus theoretical fiber pattern.

Cincinnati Milacron's Advanced Composites Technology Business Unit has created improvements by reducing the warranty costs to 0.5% of sales, considered the best in the company. Composite machine reliability figures are now measured at 98% availability for three shift operations. The Advanced Composites Technology Business Unit has also improved Cincinnati Milacron's scheduling, budgets, and reputation. These gains improve customer relationships and increase employee morale.

Reliability and Maintainability Guidelines

In 1994, Cincinnati Milacron set up a team to ensure that the company was complying with the 1993 reliability guidelines for manufacturing machinery and equipment, established by the automotive parts making and machine building community. The team developed specific checklists for use by product development groups and subsequently by operation support activities. The checklists were designed to ensure comprehensive consideration of reliability and maintainability (RAM).

The team comprised various functional disciplines whose inputs were recognized as contributing to an effective RAM product. The resulting RAM guidelines support Cincinnati Milacron's internal development and support processes, and comply with the 1993 reliability guidelines, published jointly by the Society of Automotive Engineers and the National Center for Manufacturing Sciences, Inc.

The initial application of the RAM guidelines led to the expanded use of RAM training and analysis tools. Cincinnati Milacron was able to identify problem areas and determine realistic RAM budgets for product development by obtaining field service data on existing products. Field service data and customer surveys helped Cincinnati Milacron identify customer expectations, failure mechanisms, and failure consequences. While new products developed under these guidelines are expected to show major improvements, the data available for recent model updates has already demonstrated marked improvements in the recorded values for mean time between failures (MTBF). Table 3-1 shows the improvements noted from actual customer logs on fielded machines. The normalized

Table 3-1. Field Reliability Results

1996 (Cust Log)		
500/630	#	MTBF
Model A	4	121

	1997 (AS400)		1997 (Normalized)	
500/630	#	MTBF	#	MTBF
Model A	17	633 hrs	17	200-300
Model B	34	881 hrs	34	300-450
Model C	23	1069 hrs	23	400-500

column has been adjusted from actual field service data to include comparable customer issues currently found only in customer logbooks.

Test

Precision Engineering

Cincinnati Milacron's Machine Tool Group produces precision metalworking machines and products. The company recognizes that customers want to purchase accurately-constructed machines and products as well as equipment that produces accurate products. Consequently, Cincinnati Milacron has invested considerable engineering effort in identifying and measuring those elements which contribute to inaccuracies in workpieces produced on machining centers. These measurements were then incorporated back into the product design and development processes to improve resultant accuracies.

Approximately 50% of the resultant inaccuracies are machine related with the remainder due to measurement uncertainty and process issues. Machine-related inaccuracies were further analyzed into thermal sources (slight majority) and geometry elements. Thermal sources were defined down to the level of coolant and environmental elements. Geometry elements were analyzed with allocations to the various linear, rotary, and spindle axes. Similarly, measurement uncertainty and process issues were analyzed into their constituent components. Measurement uncertainty was primarily thermal, while process issues (in descending order or significance) included choice of tooling; choice and sequence of operations; choice of fixturing and locating surfaces; and thermal contributors.

In addition to facilitating trade-offs during product development, Cincinnati Milacron's analyses have recently led to an efficient, condition-based maintenance process known as the *Fast Accuracy Condition Test*™. This process can quickly gather data on the machine, perform basic diagnostics from minimal measurements, and provide trend information indicating maintenance needs before costly scrap product is produced. The artifact and probe process for monitoring geometric alignments of machine tools by the operator is accomplished without any equipment shutdown. The use of a dedicated pallet for bringing the artifact into the machine complements the current use of a master pallet for registration. The artifact, probe, and supporting software provide the means to quickly assess a potential or apparent problem, and to gauge the process variability of a machine.

The process enables continued product output by eliminating sophisticated equipment requirements, equipment shutdown, and outside personnel. Requiring less than ten minutes, the process also offers minimal interruption for product output. Further advances are underway to improve the implementation of the automatic test system capabilities, so they will support the full range of production, field service, and customer personnel.

Production

Continuous Improvement: Machete Program

Known for its quality products, Cincinnati Milacron is committed to continuous improvement through its Total Quality Leadership approach. A key element of this approach is the Machete program which encourages total employee involvement in Cincinnati Milacron's continuous improvement efforts, and uses a disciplined process to address employee improvement suggestions.

In addition to the total employee involvement process, the Machete program provides an information data resource for parts manufacturing groups and a standardized, cost-per-hour reduction tracking mechanism. The process begins when an employee submits an improvement suggestion. Through a unique closed-loop feedback system, all submitted suggestions receive a response. Monthly

reports and quarterly reviews also provide a focus for the results. Besides improving the manufacturing methods used within a group, the Machete program encourages "best methods" sharing between the various manufacturing groups. The program offers employees an opportunity to influence corporate manufacturing processes, and helps Cincinnati Milacron increase its global competitiveness which, in turn, contributes to its profitability and employees' profit sharing program.

By implementing the Machete program, Cincinnati Milacron has strengthened its Total Quality Leadership commitment. Encouraging suggestions at the grass roots level and providing feedback on employee suggestions will assist Cincinnati Milacron in maintaining its commitment to quality and continuous improvement.

Sheet Metal Art to Part

Cincinnati Milacron is in the process of implementing a concurrent systems strategy. Part of that strategy will be the capability to design and produce a sheet metal part without paper and with minimal human analysis. Major manufacturing objectives include 100% conformance to specifications; improved facility and equipment usage; reduced manufacturing costs; and on-time delivery.

The concurrent systems strategy consists of the Engineering Database; Pro-Engineer CAD; Product Data Manager; Pro-Review Engineering Markup; ERP: Shop Floor Control (with requirements planning and finite capacity scheduling); Pro-Sheet Metal Optimation; Distributed Numerical Control; Computer Aided Process Planning; and Pro-Manufacture. The ERP and Computer Aided Process Planning are currently in the pilot implementation stage.

Traditional methods for producing a sheet metal part rely on 2-D CAD to create the flat pattern layouts. Using the 2-D engineering drawing, a numerical control programmer manually calculates the bend radii, the dimensions from edges, and the angles. Flat pattern layout errors may occur if the programmer misinterprets the 2-D engineering drawing. Average turnaround time is 60 minutes, while some complex parts may need up to 16 hours. When engineering change notices require flat pattern layouts to be updated, an engineer usually needs 30 minutes to manually incorporate the changes.

With Cincinnati Milacron's new method, a design engineer uses the Pro-Sheet Metal 3-D model to create the flat pattern layouts of new part designs. Flat pattern layouts can now be generated in about ten minutes. In addition, the new method eliminates the chance of interpretation errors. Engineering change notices for updates can be handled within minutes, since the flat pattern layout is parametrically driven by the Pro-Sheet Metal 3-D model.

Cincinnati Milacron's concurrent system will improve part quality through Computerized Numerical Control part manufacturing and decrease part costs, program prove-out times, and scrap rates. In addition, the system will reduce the leadtime from part design to part manufacturing and the costs of indirect activities (e.g., process planning, numerical control programming, tool design).

Unit Assembly Test Stands

Cincinnati Milacron's Machine Tool Group has developed and implemented four subassembly test units (Tool Changer Tester, Tool Storage Unit Tester, Subtable Unit Tester, and Automatic Work Changer Tester) for its assembly process. Developed as low cost and low technology ideas, these units reduce costs and runoff time of the machining centers; improve the quality and reliability of products; ensure consistent test procedures are followed; and reduce runoff times for acceptance testing of finished products.

The Tool Changer Tester simulates the tool mounting system of the machining center including the spindle, chain, and transfer arm. The unit verifies the electrical system and hydraulic line connections, checks cycle times, and runs reliability tests to ensure a proven subassembly is provided for final assembly. Benefits include reducing electrical technicians' time by two hours per machine and eliminating rework by 95% at the machine runoff.

The Tool Storage Unit Tester is used to run-in the tool storage transfer chain, so that proper tension and clearances can be adjusted after the initial two-hour run. After the initial run, the chain tension will loosen up and must be reset to the proper specifications. The unit also verifies that the electrical connections and components are working properly.

The Subtable Unit Tester simulates the table interface with the machine to verify electrical continuity, good hydraulic seals, and proper tubing connections, and to ensure there are no leaks. Proper interface between the table and the machine is critical due to the intense labor required to remove and repair the machine should any problems occur after mounting. The unit is also used to

set the pallet registration to a master gauge, which ensures table positioning accuracies. The Subtable Unit Tester unit has reduced the runoff time for the finished machine by 20 hours and produced an overall savings of 12 hours per machine.

The Automatic Work Changer Tester is a simulated table, load station, and pallet load capacity tester. The unit tests the extensive wiring required for assembly, and sets up the stops and proximity switches prior to final assembly to the machine and the installation of covers and guards. The Automatic Work Changer Tester has reduced electrical start ups by eight hours per machine, and provides the necessary reliability tests to ensure proper positioning and transfer of fully-loaded pallets.

The use of subassembly units, prior to the assembly of finished machines, has proven beneficial to Cincinnati Milacron. These units are very cost effective in reducing runoff test times and improving the quality and reliability of finished machines.

Management

Safety and Wellness for Employees Program

The Safety and Wellness for Employees program represents an important aspect of Cincinnati Milacron's commitment to its employees. Through this program, Cincinnati Milacron provides and maintains safe, healthy work environments; promotes safety and wellness training; and complies with safety requirements and regulations.

Based on a 50-chapter Corporate Safety and Health Manual, Cincinnati Milacron's program provides a full-time medical facility, a full-time safety specialist, 23 certified emergency medical technicians, and more than 40 different safety training classes and 20 wellness programs conducted throughout the year (e.g., free mammography and prostate screenings, Weight Watchers program, exercise classes). Other features include employee health counseling, blood drives, and a hearing conservation program.

Cincinnati Milacron's Safety and Wellness for Employees program meets or exceeds OSHA's safety and health training regulations. The company has also established an ergonomic team to investigate and resolve ergonomic-related issues and concerns. Through its program, Cincinnati Milacron demonstrates its commitment to the safety and well being of its employees and their working environment.

Service Parts Division

Cincinnati Milacron's Service Parts Division (SPD) provides post sales service and supplies all repair parts for milling, grinding, and turning machines built since 1884. SPD consists of customer communications, technical services, inventory control, expediting, purchasing, pricing, microfilming, programming, assembly, shipping, and warehousing. Growth of this division has occurred mainly through the Original Equipment Manufacturer Sales; Repair and Exchange; and Engineering Service Departments. Essential to SPD's operation are accessibility and part availability.

A few years ago, SPD conducted a study on accessibility. Customer feedback indicated that 44% of initial telephone calls were handled by an answering machine. Despite the advances in telecommunications, customers still prefer to talk to a live representative from customer service. Based on the findings, SPD revised its telephone system and installed the Automatic Call Distributor (ACD) system. The ACD system (Table 3-2) distributes calls to the first-available open line and reduces the number of messages handled by an answering machine. Today, SPD has an 11% abandon rate (number of messages left on an answering machine), with a goal of 5%. The abandon rate, measured on a daily or hourly basis, is continuously monitored to enhance SPD's post sales service.

Table 3-2. Evolution of Phone System

Pre 1991	Feb 1991	Jan 1997
Answering Machines & AVT Voice Mail Define Geographic Territories	ACD Phone System Phase I Replaces Answering Machines & AVT Voice Mail	ACD Phone System Phase II No Geographic Territories 1-800 Group/Inside Sales
Average Daily Calls 450	Average Daily Calls 450	Average Daily Calls 450
Daily Messages 200	Daily Messages 100	Daily Messages 40
Answered 56% "Live"	Answered 78% "Live"	Answering 89% "Live"

Parts availability is also critical to customer satisfaction. SPD maintains the records on more than 280,000 different parts, and the bin locations for about 70,000 different items. Inventory is based on usage and service levels (the number of parts in stock when requested by a customer). SPD also performs daily reviews of its active and obsolete stock. If available, parts ordered by customers are shipped daily. Cincinnati Milacron measures the success rate of its parts availability at the service level. Currently, SPD has an 86% service level, with a goal of 90%.

Appendix A

Table of Acronyms

Acronym	Definition
ACD	Automatic Call Distributor
ATS	Automatic Test System™
FEA	Finite Element Analysis
FMC	Flexible Machining Cell
MTBF	Mean Time Between Failures
MTG	Machine Tool Group
PEMS	Precision Engineering Measurement System
RAM	Reliability and Maintainability
SPD	Service Parts Division

Appendix B

BMP Survey Team

Team Member	Activity	Function
Larry Robertson (812) 854-5336	**Crane Division** Naval Surface Warfare Center Crane, IN	**Team Chairman**
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Sam Hart (423) 574-2501	**Oak Ridge Centers for Manufacturing Technology** Oak Ridge, TN	**Team Leader**
Jack Tamargo (707) 642-4267	**BMP Satellite Center Manager** Vallejo, CA	
	Management & Logisitics Team	
Rick Purcell (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Team Leader**
John Horton (817) 763-3060	**Lockheed Martin Tactical Aircraft Systems** Fort Worth, TX	

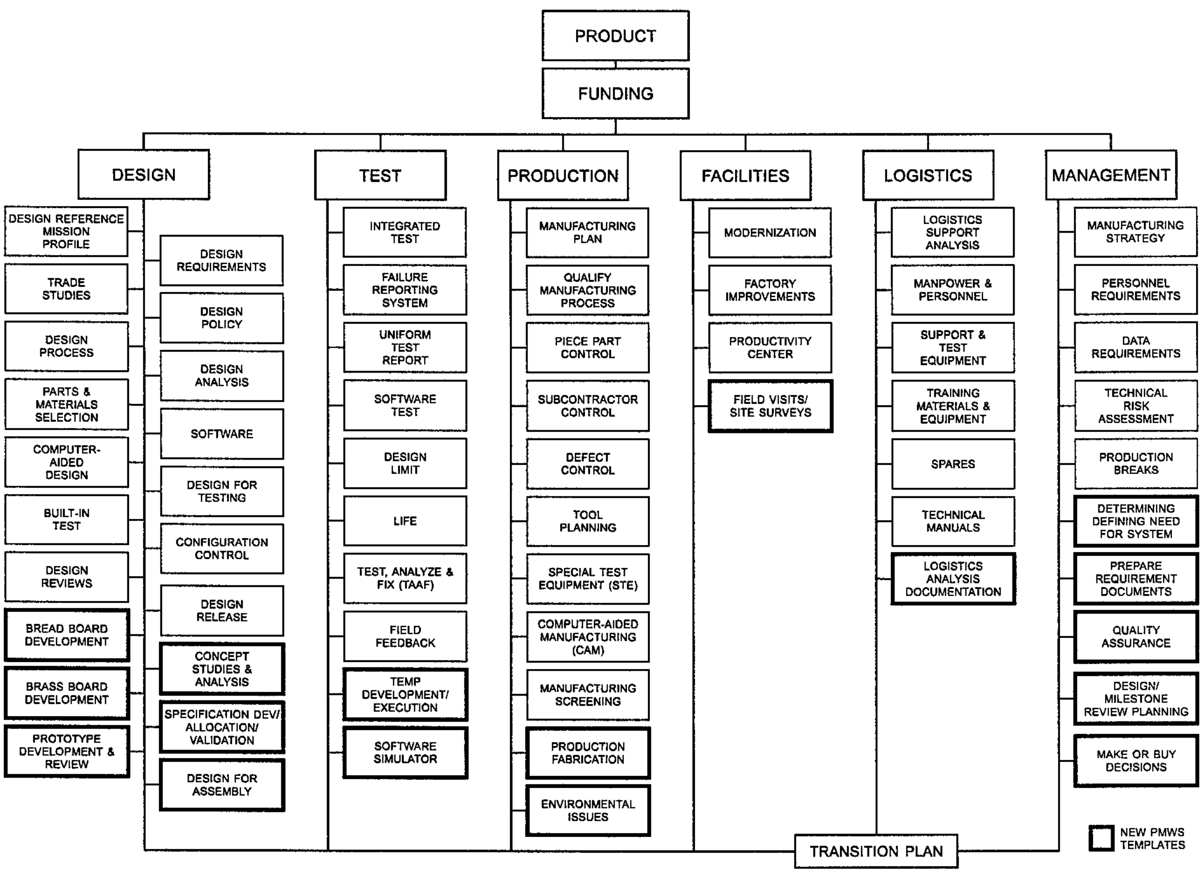
Appendix C

Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, *Transition from Development to Production* document. This publication defines the proper tools—or templates—that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition process by addressing it as an *industrial* process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

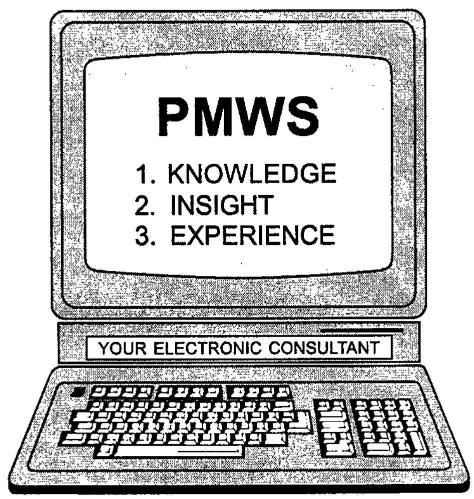
The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

"CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION"



Appendix D
BMPnet and the Program Manager's WorkStation

The BMPnet, located at the Best Manufacturing Practices Center of Excellence (BMPCOE) in College Park, Maryland, supports several communication features. These features include the Program Manager's WorkStation (**PMWS**), electronic mail and file transfer capabilities, as well as access to Special Interest Groups (SIGs) for specific topic information and communication. The BMPnet can be accessed through the World Wide Web (at http://www.bmpcoe.org), through free software that connects directly over the Internet or through a modem. The PMWS software is also available on CD-ROM.



PMWS provides users with timely acquisition and engineering information through a series of interrelated software environments and knowledge-based packages. The main components of PMWS are KnowHow, SpecRite, the Technical Risk Identification and Mitigation System (TRIMS), and the BMP Database.

KnowHow is an intelligent, automated program that provides rapid access to information through an intelligent search capability. Information currently available in KnowHow handbooks includes Acquisition Streamlining, Non-Development Items, Value Engineering, NAVSO P-6071 (Best Practices Manual), MIL-STD-2167/2168 and the DoD 5000 series documents. KnowHow cuts document search time by 95%, providing critical, user-specific information in under three minutes.

SpecRite is a performance specification generator based on expert knowledge from all uniformed services. This program guides acquisition personnel in creating specifications for their requirements, and is structured for the build/approval process. SpecRite's knowledge-based guidance and assistance structure is modular, flexible, and provides output in MIL-STD 961D format in the form of editable WordPerfect® files.

TRIMS, based on DoD 4245.7-M (the transition templates), NAVSO P-6071, and DoD 5000 event-oriented acquisition, helps the user identify and rank a program's high-risk areas. By helping the user conduct a full range of risk assessments throughout the acquisition process, TRIMS highlights areas where corrective action can be initiated before risks develop into problems. It also helps users track key project documentation from concept through production including goals, responsible personnel, and next action dates for future activities.

The **BMP Database** contains proven best practices from industry, government, and the academic communities. These best practices are in the areas of design, test, production, facilities, management, and logistics. Each practice has been observed, verified, and documented by a team of government experts during BMP surveys.

Access to the BMPnet through dial-in or on Internet requires a special modem program. This program can be obtained by calling the BMPnet Help Desk at (301) 403-8179 or it can be downloaded from the World Wide Web at http://www.bmpcoe.org. To receive a user/e-mail account on the BMPnet, send a request to helpdesk@bmpcoe.org.

Appendix E
Best Manufacturing Practices Satellite Centers

There are currently six Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; identify regional experts for inclusion in the BMPnet SIG e-mail; and train regional personnel in the use of BMP resources such as the BMPnet.

The six BMP satellite centers include:

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(423) 576-5532
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tgraham@bmpcoe.org

Appendix F

Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Sciences and Technology Program established the following Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and Navy centers and laboratories. These COEs are consortium-structured for industry, academia, and government involvement in developing and implementing technologies. Each COE has a designated point of contact listed below with the individual COE information.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and promote exemplary manufacturing and business practices and to disseminate this information to the U.S. Industrial Base. The BMPCOE was established by the Navy's BMP program, Department of Commerce's National Institute of Standards and Technology, and the University of Maryland at College Park, Maryland. The BMPCOE improves the use of existing technology, promotes the introduction of improved technologies, and provides non-competitive means to address common problems, and has become a significant factor in countering foreign competition.

Point of Contact:
Mr. Ernie Renner
Best Manufacturing Practices Center of Excellence
4321 Hartwick Road
Suite 400
College Park, MD 20740
(301) 403-8100
FAX: (301) 403-8180
ernie@bmpcoe.org

Center of Excellence for Composites Manufacturing Technology

The Center of Excellence for Composites Manufacturing Technology (CECMT) provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors. The CECMT is managed by the GreatLakes Composites Consortium and represents a collaborative effort among industry, academia, and government to develop, evaluate, demonstrate, and test composites manufacturing technologies. The technical work is problem-driven to reflect current and future Navy needs in the composites industrial community.

Point of Contact:
Dr. Roger Fountain
Center of Excellence for Composites Manufacturing Technology
103 Trade Zone Drive
Suite 26C
West Columbia, SC 29170
(803) 822-3705
FAX: (803) 822-3730
frglcc@aol.com

Electronics Manufacturing Productivity Facility

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of industry, university, and government participants, led by the American Competitiveness Institute under a CRADA with the Navy.

Point of Contact:
Mr. Alan Criswell
Electronics Manufacturing Productivity Facility
Plymouth Executive Campus
Bldg 630, Suite 100
630 West Germantown Pike
Plymouth Meeting, PA 19462
(610) 832-8800
FAX: (610) 832-8810
http://www.engriupui.edu/empf/

National Center for Excellence in Metalworking Technology

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. The NCEMT, operated by Concurrent Technologies Corporation, helps the Navy and defense contractors improve

manufacturing productivity and part reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:
Mr. Richard Henry
National Center for Excellence in Metalworking Technology
1450 Scalp Avenue
Johnstown, PA 15904-3374
(814) 269-2532
FAX: (814) 269-2799
henry@ctc.com

Navy Joining Center

The Navy Joining Center (NJC) is operated by the Edison Welding Institute and provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues.

Point of Contact:
Mr. David P. Edmonds
Navy Joining Center
1100 Kinnear Road
Columbus, OH 43212-1161
(614) 487-5825
FAX: (614) 486-9528
dave_edmonds@ewi.org

Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality energetics. The focus of the EMTC is on process technology with a goal of reducing manufacturing costs while improving product quality and reliability. The COE also maintains a goal of development and implementation of environmentally benign energetics manufacturing processes.

Point of Contact:
Mr. John Brough
Energetics Manufacturing Technology Center
Indian Head Division
Naval Surface Warfare Center
Indian Head, MD 20640-5035
(301) 743-4417
DSN: 354-4417
FAX: (301) 743-4187
mt@command.nosih.sea06.navy.mil

Manufacturing Science and Advanced Materials Processing Institute

The Manufacturing Science and Advanced Materials Processing Institute (MS&AMPI) is comprised of three centers including the National Center for Advanced Drivetrain Technologies (NCADT), The Surface Engineering Manufacturing Technology Center (SEMTC), and the Laser Applications Research Center (LaserARC). These centers are located at The Pennsylvania State University's Applied Research Laboratory. Each center is highlighted below.

Point of Contact for MS&AMPI:
Mr. Henry Watson
Manufacturing Science and Advanced Materials Processing Institute
ARL Penn State
P.O. Box 30
State College, PA 16804-0030
(814) 865-6345
FAX: (814) 863-1183
hew2@psu.edu

- **National Center for Advanced Drivetrain Technologies**
  The NCADT supports DoD by strengthening, revitalizing, and enhancing the technological capabilities of the U.S. gear and transmission industry. It provides a site for neutral testing to verify accuracy and performance of gear and transmission components.

  Point of Contact for NCADT:
  Dr. Suren Rao
  NCADT/Drivetrain Center
  ARL Penn State
  P.O. Box 30
  State College, PA 16804-0030
  (814) 865-3537
  FAX: (814) 863-6185
  http://www.arl.psu.edu/drivetrain_center.html/

- **Surface Engineering Manufacturing Technology Center**

  The SEMTC enables technology development in surface engineering—the systematic and rational modification of material surfaces to provide desirable material characteristics and performance. This can be implemented for complex optical, electrical, chemical, and mechanical functions or products that affect the cost, operation, maintainability, and reliability of weapon systems.

  Point of Contact for SEMTC:
  Dr. Maurice F. Amateau
  SEMTC/Surface Engineering Center
  P.O. Box 30
  State College, PA 16804-0030
  (814) 863-4214
  FAX: (814) 863-0006
  http://www/arl.psu.edu/divisions/arl_org.html

- **Laser Applications Research Center**

  The LaserARC is established to expand the technical capabilities of DOD by providing access to high-power industrial lasers for advanced material processing applications. LaserARC offers basic and applied research in laser-material interaction, process development, sensor technologies, and corresponding demonstrations of developed applications.

  Point of Contact for LaserARC:
  Mr. Paul Denney
  Laser Center
  ARL Penn State
  P.O. Box 30
  State College, PA 16804-0030
  (814) 865-2934
  FAX: (814) 863-1183
  http://www/arl.psu.edu/divisions/arl_org.html

Gulf Coast Region Maritime Technology Center

The Gulf Coast Region Maritime Technology Center (GCRMTC) is located at the University of New Orleans and will focus primarily on product developments in support of the U.S. shipbuilding industry. A sister site at Lamar University in Orange, Texas will focus on process improvements.

Point of Contact:
Dr. John Crisp
Gulf Coast Region Maritime Technology Center
University of New Orleans
Room N-212
New Orleans, LA 70148
(504) 286-3871
FAX: (504) 286-3898

Appendix G
Completed Surveys

As of this publication, 91 surveys have been conducted by BMP at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPnet. Requests for copies of recent survey reports or inquiries regarding the BMPnet may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 400
College Park, MD 20740
Attn: Mr. Ernie Renner, Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
ernie@bmpcoe.org

1985	Litton Guidance & Control Systems Division - Woodland Hills, CA
1986	Honeywell, Incorporated Undersea Systems Division - Hopkins, MN (Alliant TechSystems, Inc.) Texas Instruments Defense Systems & Electronics Group - Lewisville, TX General Dynamics Pomona Division - Pomona, CA Harris Corporation Government Support Systems Division - Syosset, NY IBM Corporation Federal Systems Division - Owego, NY Control Data Corporation Government Systems Division - Minneapolis, MN
1987	Hughes Aircraft Company Radar Systems Group - Los Angeles, CA ITT Avionics Division - Clifton, NJ Rockwell International Corporation Collins Defense Communications - Cedar Rapids, IA UNISYS Computer Systems Division - St. Paul, MN (Paramax)
1988	Motorola Government Electronics Group - Scottsdale, AZ General Dynamics Fort Worth Division - Fort Worth, TX Texas Instruments Defense Systems & Electronics Group - Dallas, TX Hughes Aircraft Company Missile Systems Group - Tucson, AZ Bell Helicopter Textron, Inc. - Fort Worth, TX Litton Data Systems Division - Van Nuys, CA GTE C^3 Systems Sector - Needham Heights, MA
1989	McDonnell-Douglas Corporation McDonnell Aircraft Company - St. Louis, MO Northrop Corporation Aircraft Division - Hawthorne, CA Litton Applied Technology Division - San Jose, CA Litton Amecom Division - College Park, MD Standard Industries - LaMirada, CA Engineered Circuit Research, Incorporated - Milpitas, CA Teledyne Industries Incorporated Electronics Division - Newbury Park, CA Lockheed Aeronautical Systems Company - Marietta, GA Lockheed Corporation Missile Systems Division - Sunnyvale, CA Westinghouse Electronic Systems Group - Baltimore, MD General Electric Naval & Drive Turbine Systems - Fitchburg, MA Rockwell International Corporation Autonetics Electronics Systems - Anaheim, CA TRICOR Systems, Incorporated - Elgin, IL
1990	Hughes Aircraft Company Ground Systems Group - Fullerton, CA TRW Military Electronics and Avionics Division - San Diego, CA MechTronics of Arizona, Inc. - Phoenix, AZ Boeing Aerospace & Electronics - Corinth, TX Technology Matrix Consortium - Traverse City, MI Textron Lycoming - Stratford, CT

1991	*Resurvey of Litton Guidance & Control Systems Division* - Woodland Hills, CA Norden Systems, Inc. - Norwalk, CT Naval Avionics Center - Indianapolis, IN United Electric Controls - Watertown, MA Kurt Manufacturing Co. - Minneapolis, MN MagneTek Defense Systems - Anaheim, CA Raytheon Missile Systems Division - Andover, MA AT&T Federal Systems Advanced Technologies and AT&T Bell Laboratories - Greensboro, NC and Whippany, NJ *Resurvey of Texas Instruments Defense Systems & Electronics Group* - Lewisville, TX
1992	Tandem Computers - Cupertino, CA Charleston Naval Shipyard - Charleston, SC Conax Florida Corporation - St. Petersburg, FL Texas Instruments Semiconductor Group Military Products - Midland, TX Hewlett-Packard Palo Alto Fabrication Center - Palo Alto, CA Watervliet U.S. Army Arsenal - Watervliet, NY Digital Equipment Company Enclosures Business - Westfield, MA and Maynard, MA Computing Devices International - Minneapolis, MN *(Resurvey of Control Data Corporation Government Systems Division)* Naval Aviation Depot Naval Air Station - Pensacola, FL
1993	NASA Marshall Space Flight Center - Huntsville, AL Naval Aviation Depot Naval Air Station - Jacksonville, FL Department of Energy Oak Ridge Facilities (Operated by Martin Marietta Energy Systems, Inc.) - Oak Ridge, TN McDonnell Douglas Aerospace - Huntington Beach, CA Crane Division Naval Surface Warfare Center - Crane, IN and Louisville, KY Philadelphia Naval Shipyard - Philadelphia, PA R. J. Reynolds Tobacco Company - Winston-Salem, NC Crystal Gateway Marriott Hotel - Arlington, VA Hamilton Standard Electronic Manufacturing Facility - Farmington, CT Alpha Industries, Inc. - Methuen, MA
1994	Harris Semiconductor - Melbourne, FL United Defense, L.P. Ground Systems Division - San Jose, CA Naval Undersea Warfare Center Division Keyport - Keyport, WA Mason & Hanger - Silas Mason Co., Inc. - Middletown, IA Kaiser Electronics - San Jose, CA U.S. Army Combat Systems Test Activity - Aberdeen, MD Stafford County Public Schools - Stafford County, VA
1995	Sandia National Laboratories - Albuquerque, NM Rockwell Defense Electronics Collins Avionics & Communications Division - Cedar Rapids, IA *(Resurvey of Rockwell International Corporation Collins Defense Communications)* Lockheed Martin Electronics & Missiles - Orlando, FL McDonnell Douglas Aerospace (St. Louis) - St. Louis, MO *(Resurvey of McDonnell-Douglas Corporation McDonnell Aircraft Company)* Dayton Parts, Inc. - Harrisburg, PA Wainwright Industries - St. Peters, MO Lockheed Martin Tactical Aircraft Systems - Fort Worth, TX *(Resurvey of General Dynamics Fort Worth Division)* Lockheed Martin Government Electronic Systems - Moorestown, NJ Sacramento Manufacturing and Services Division - Sacramento, CA JLG Industries, Inc. - McConnellsburg, PA
1996	City of Chattanooga - Chattanooga, TN Mason & Hanger Corporation - Pantex Plant - Amarillo, TX Nascote Industries, Inc. - Nashville, IL Weirton Steel Corporation - Weirton, WV NASA Kennedy Space Center - Cape Canaveral, FL

1997	Headquarters, U.S. Army Industrial Operations Command - Rock Island, IL SAE International and Performance Review Institute - Warrendale, PA Polaroid Corporation - Waltham, MA Cincinnati Milacron, Inc. - Cincinnati, OH